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Abstract: The paper describes a portable device for recording eye movements through Electrooculography (EOG). The gained bio signal can be used for monitoring the vigilance or basic eye control commands. The measurement is done with sticky electrodes; therefore it is non-invasive and easy to use. A special dedicated hardware device was developed for the purpose of data acquisition. The device has been tailored to be used in real life environments. The device allows rechargeable battery powered data acquisition of 3 EOG channels with 24bit resolution and 250Hz sampling rate per channel, over a period of up to 10 hours. Time information is provided by a built-in real time clock. The collected data is pre-processed and can be stored on a memory card or streamed directly via Bluetooth using a serial port profile to a mobile device. The mobile application can be used for data post-processing as well as for the adjustment of measurement device settings.

Keywords: Electrooculography, Bluetooth Serial Port Profile, Android

1 Introduction

There are a large number of people living with some kind of disability.Elderly people become handicapped and consequently limited in their personal autonomy too. Assisted Ambient Living deals with assistive systems in response to disability problem. Most of these systems are controlled through traditional methods, like mouse, keyboard or joystick input.

For physically disabled or handicapped people it is necessary to employ special interfaces that must be simple, robust and easy to integrate in daily routine. With data collected on basis of daily routines and user behavior analysis the algorithm can be optimized so that accurateness of such devices increases significantly.

2 Electrooculography

Electrooculography (EOG) is a common measurement method for eye movement recognition using electrodes to measure the resting potential of the retina. Five electrodes are used for signal generation. The positions of the electrodes are shown in figure 1.

They are placed on the right and left side from the eyes for the horizontal movements, as well as below and above them for vertical transaction.
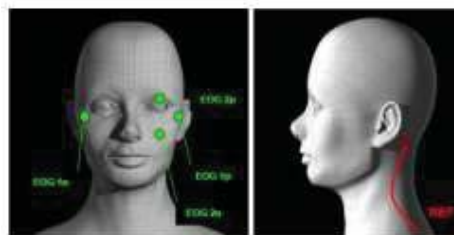

Fig. 1. On the left figure the position of the Electrode for horizontal (EOG 1p and EOG 1p) and vertical (EOG 2p and EOG 2n) movement are shown. On the right figure the position for the referee electrode behind the ear are shown.

The fifth electrode is used as ground electrode and is placed in the middle auf the brow or behind the ear. The human eye is similar to an electric dipole. By moving the eye on the front side it moves closer to one electrode by moving backwards it moves closer to the other electrode. This change of the electric potential between the electrodes is measured [1]. Figure 2 shows the schematic EOG signal generation for right and left eye movements. For the vertical channel the same principle is valid.
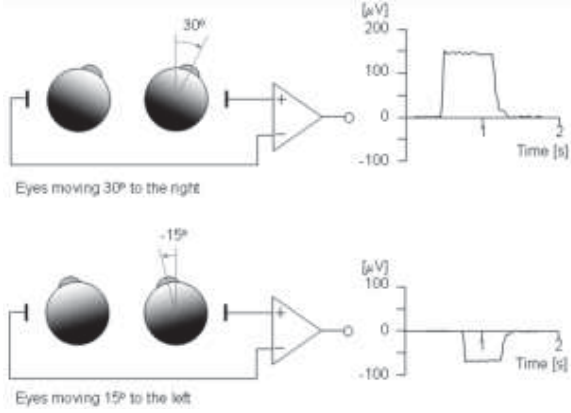

Fig. 2. Schematic horizontal EOG signal generation [2]

3 Devices

The hardware is compliant with essential requirements of the medical device directive and meets the demands of EN 60601-1 (basic requirements) and EN 60601-1-2 (EMC). The device has a wearable size with dimensions WxLxH 64x86x30 mm. The device port can be connected either to a medical charger or the application part to prevent a simultaneous connection of patient and main supply. For power supply a lithium polymer accumulator is used. The operation time is approximately 10 hours. As user interface serves a switch with on/off function. The user start command is implemented in form of a separate button. The block diagram of the EOG Data
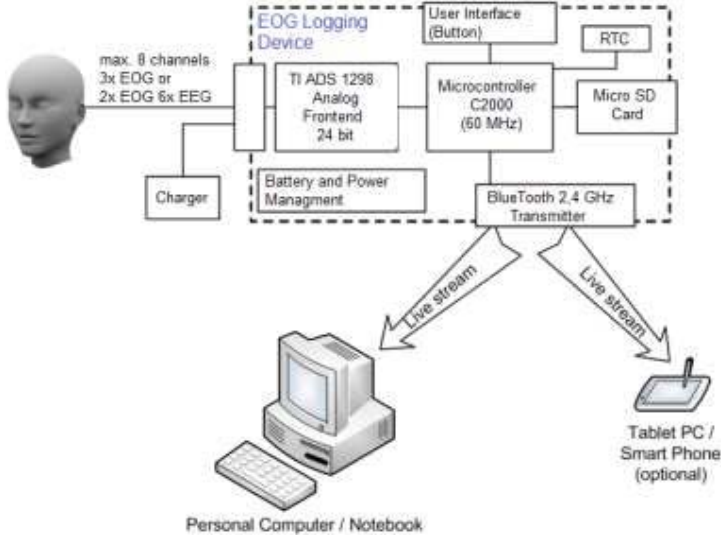

Fig. 3. Block Diagram of the logging device

Logging device is shown in figure 3. For the measurement purposes a 24-bit analog-to- digital converter with 8 channels is used. The ADS1298 from Texas Instruments is built for bio potential measurement [3]. The data rate is set to 250 samples per second (SPS). At this rate the noise performance is most suitable. A programmable gain amplifier is included. The differential input/differential output amplifier can programmed with seven gain levels. A built in right leg drive amplifier and Lead-Off detection is included. With a serial peripheral interface (SPI) the date is sent to the main controlling unit. This 32-bit microcontroller C2000 from Texas Instrument manages and pre-processes the acquainted data to store them on a micro SD memory card or send them via Bluetooth to another device. For SD memory card is a Kyocera Type 5138 connector is used and controlled by the microcontroller. A real-time clock is connected via I2C Bus to the microcontroller. The M41T82 is a real-time clock with low power consumption [4]. For communication with computers, tablet or smart phone devices the microcontroller is armed with the Bluetooth transmitter AMB 2300 [5]. This IC provides a complied Bluetooth solution and is connected via SPI to the microcontroller unit. The Bluetooth configuration is handled by the microcontroller application. It is defined as a Bluetooth Master device with a Serial Port profile (SPP).

4 Application for mobile Device

Mobile devices can be used to study the user within their daily environment. The setup of a concurrent measurement should be simple and should require no special knowledge. For reasonable data the main settings, e.g. the gain or correct time, should be adapted for each measurement. By means of a tablet or Smartphone application it is possible to fulfill the above mentioned requirements. Furthermore the mobile device application can be used for real time analysis of the gained measurement values.
Currently an application in Android 4.x is implemented for the logging device. The first basic step for a real-time application is the faultless connection with the logging device via Bluetooth. Following features are realized in the current version of the mobile application: It is possible to search and connect to an EOG logging device via Bluetooth. When a connection is established the real-time clock will be updated with the current mobile device time. Measurement settings can be applied and modified through the mobile application (e.g. gain per channel). The received data can be stored on the device in a simple text file. At the moment there are three view modes: one channel over time view, two channels over time view and a XY view. The XY view combines the horizontal and the vertical EOG signals to a single view. In the following two sections the most imported parts of the application are described.

4.1 Bluetooth in Android

Most Android devices armed with Bluetooth are based on Android Development

Tools (ADT) which provides a set of instructions for communication.
The permissions BLUETOOTH and BLUETOOTH_ADMIN must be set in the Android manifest.xml file as a request for function usage. For establishing a connection to another Bluetooth device the 48-bit MAC address of the device and the
18-bit Universally Unique Identifier (UUID) is necessary. The UUID comprises information about the profile used for communication. The standard UUID for SPP can be found in the specification for Bluetooth [6].The first section defines the profile; in case of the serial port profile it is 00001101. The following source code snippet is a basic implementation for a SPP communication with a known Bluetooth device. The received data is stored in a JAVA InputStream and data can be sent to the device via a OutputStream.

```
import android.bluetooth.BluetoothAdapter; import android.bluetooth.BluetoothDevice; import android.bluetooth.BluetoothSocket;

private BluetoothAdapter mbtAdapter= null;

//check if Bluetooth Adapter available

mbtAdapter= BluetoothAdapter.getDefaultAdapter();
```

if (mbtAdapter == null)

{ Toast.makeText(this, "Bluetooth is not available",

Toast.LENGTH_LONG).show();

finish();

return;

}

//turn on Bluetooth Adapter if is not enabeld if(!mbtAdapter.isEnabled())

{ Intent enableIntent = new

Intent(BluetoothAdapter.ACTION_REQUEST_ENABLE);

startActivityForResult(enableIntent,

REQUEST_ENABLE_BT);

}

private String address="00:18:DA:01:AA:DE"; private static final UUID MY_UUID = UUID.fromString("00001101-0000-1000-8000-00805F9B34FB");

// Get a BluetoothSocket from given BluetoothDevice mbtDevice = mbtAdapter.getRemoteDevice(address); BluetoothSocket mbtSocket = mbtDevice.createRfcommSocketToServiceRecord(MY_UUID); mbtSocket.connect();

InputStream mbtInStream = mbtSocket.getInputStream(); OutputStream mbtOutStream = mbtSocket.getOutputStream();

//Get the BluetoothSocket input an output streams mbtInputStream =

mbtOutputStream = mbtSocket.getOutputStream();

The Bluetooth server in the above source code is provided by the logging device. The Android sample application Bluetooth Chat provides a short reference implementation for client and server communication and sending text messages via Bluetooth to other devices [7]. For continuous data transmission the Bluetooth connection should not be executed in the main activity thread. It is recommended to implement the communication within a separate thread.

4.2 Real Time Graph in Android

After received 250 data frames per second the data must be pre-processed. The data must be human-readable so that the user is able to evaluate the data and adjust measurement settings if necessary. With a dynamic plot of the measured EOG signal a quick evaluation is possible and effect of change settings is easy to review.
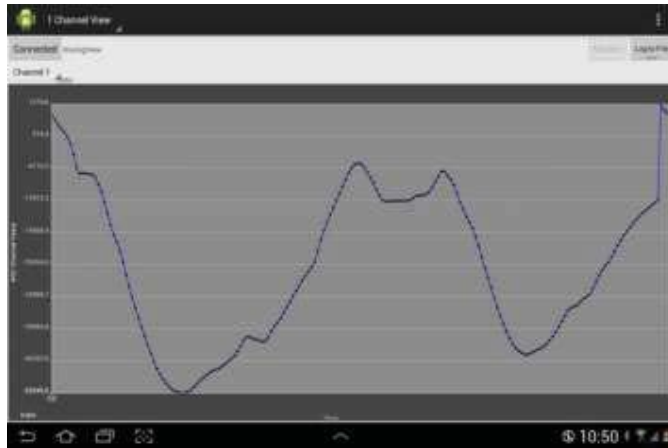
Fig. 4. Screenshot of application with horizontal EOG Signal

For Android are many third-party libraries can be found. This application uses the project AndroidPlot, which is licensed under the Apache License, Version 2.0. Therefore the library can be used for scientific projects. Some examples are found at the homepage of the developer [8]. The programmed application used the "SimpleXYSeries" class set in connection with a line plot graph. The values for Y are stored in a viable from type "ArrayList". For the X values also a variable from type "ArrayList" is used for positioning of the lists Y. For real time applications the refreshing rate of the graph is essential. The rate depends of the maximum number of values and on the fact of whether the re-draw routine is blocking or not. For AndroidPlot 0.5.0 a refreshing rate of 100 Hz with around 400 points supply good results [9]. Figure 4 shows a screenshot of the application. The horizontal axis of the EOG Signal represents ADC values over time. These values are raw values. The refreshing rate is down-sampled with a factor of 3.

5 Application fields for measured EOG signals

5.1 Vigilance

For some professions vigilance is a vital attribute of the job description, e.g. professional drivers or air-traffic controller and pilots. Breaks for rest are ruled by laws based on statistics instead of real conditions. With vigilance control it is possible
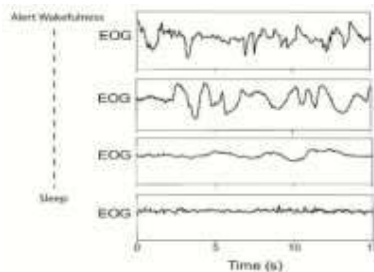

Fig. 5. EOG Signal for different vigilance conditions [10]

to find the best time for a break based on actual circumstances. Figure 5 shows the change of the EOG signal between alert, wakefulness and sleep. Based on data retrieved from the logging device a suitable algorithmn can be developed for an online moitoring system.

5.2 Extreme eye position recognition

An interesting application for handicapped people is control with the help of eye movement gestures. With different gestures a command e.g. "next page" or "start a program" can be assembled from basic eye movements in extreme positions. Common eye gestures are: look left, right, up or down. A currently unsolved problem for our pattern recognition algorithms is unconscious blinking: by one blink the eyes are going up. In Figure 6 a vertical EOG signal is shown with an "up - down – up" order followed by a "down with two unconscious blinks while looking down". The blue signal is the original raw signal. The green is the signal filtered by the recognition algorithmic. With the signal drift and the two consecutive blinks it is difficult to recognize if it is one movement to down or more, e.g. two or three. With optimized algorithms a reliable recognition can be achieved.
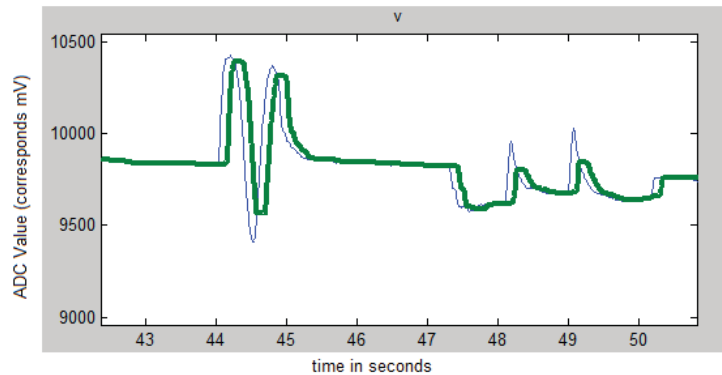

Fig. 6. Vertical EOG Signal with up down recognition and blinking

6 Future Work

Besides algorithm improvement, customizing and optimizing for different application fields, the development and enhancement of the hardware is an important ongoing and future task. For daily wearable devices the electrodes have to be changed from sticky to dry and the electrodes should be combined with suitable measuring equipment to a comfortable wearable device. One of the next development steps is to create a computer mouse controlled by eye.

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